Study on the behavior of blood in static magnetic field

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Abstract: The proposed work investigates the effects of static magnetic field on blood sample when exposed to non-uniform static magnetic field of 0.35 T. The curves have been plotted between wavelength and transmittance T% with the help of spectrophotometer. Three sets of curves are obtained viz. before placing in magnetic field, after placing in magnetic field of 0.35 T for 20 min and then after 20 min of removing the field. The change in nature of these curves shows that there is an effect of magnetic field on blood. The most probable reasons for these changes are magnetization of blood and increase in energy of blood due to the magnetic field. Thus it can be concluded that the exposure to the magnetic field caused the effect.

Key words: Transmittance, Spectrophotometer

I. INTRODUCTION

The blood contains paramagnetic and diamagnetic atoms and molecules, so it can be considered as a bio-magnetic fluid, which is an essential part of living creatures. The presence of a static magnetic field affects its behavior.

The blood consists of intercellular proteins, red blood cells containing hemoglobin – a form of iron oxide, white blood cells, platelets, water etc. The effects of static magnetic field are due to the orientation of various constituents of blood.

According to Pauling et al. [1] diamagnetism and paramagnetism are two properties which are affected by magnetic field. The blood is diamagnetic when oxygenated and behaves as paramagnetic when deoxygenated. Motta et al. [2] calculated the magnetic susceptibility of blood, which for oxygenated blood is -6.6×10^{-7} and for deoxygenated blood is 3.5×10^{-7}.

Heidelberger et al. [3] and Melville et al. [4] in their work use a strong magnetic field gradient to separate healthy cells and malaria infected cells. A similar study was conducted by Shiga et al. [5] & Chen et al. [6] in which they used inhomogeneous magnetic field to study blood circulation and its results show the paramagnetic behavior of erythrocytes.

Ueno et al. [7] studied the effect of magnetic field on fibrin, component of blood. The blood contains fibrinogen as a blood coagulant. Under the influence of protease thrombin, the fibrinogen changes to fibrin, which are polymerized to diamagnetic long fibrin molecules which are affected by the presence of magnetic field. During injury these fibrin fibres form web gel. When placed in magnetic field fibrin moves from higher field value to lower magnetic field. Ueno et al. [7] showed that fibrin gel formed at 8 T is more soluble in water containing plasma in comparison to the absence of field.

Iwasaka et al. [8] studied the effects of homogenous magnetic field gradient dB/dy < 4T/m on the enzymatic activities of plasmin and found no changes in maximum velocity. Also the value of the Michaelis constant of plasmin remained same as that at 8T. Lipids and proteins present in blood were also seen to be magnetically sensitive. Most of the proteins showed diamagnetic behavior in the SMF and very few displayed paramagnetic behavior. Costa Ribiro et al. [9] and Torbet et al. [10] found that static magnetic field forces the sickle cell hemoglobin and actin to orient themselves.

II. MAGNETIC SUSCEPTIBILITY AND ORIENTATION INTERACTION IN THE SMF

The Magnetic susceptibility of a material determines up to what extent the dipole moment is induced in it. The electronic, optical and magnetic properties of a molecule are based on the electronic configuration of the constituent atoms and the chemical bonds between them. When placed in magnetic field it may possible that the behavior of constituent atoms of molecule is different from each other. In that case a torque is exerted on the molecule whose magnitude and direction depends upon the difference in susceptibility i.e. ($\Delta \chi = \chi_1 - \chi_2$) where χ_1 and χ_2 are susceptibility along two different directions. The value of susceptibility is –ve for diamagnetic atom and direction of induced dipole moment is opposite to the field direction H. Hence a torque is exerted on the aggregates of molecules placed in SMF. Biological molecules are anisotropic super molecules which align themselves in the magnetic field. The main reason of anisotropic susceptibility is their internal structure.

The biological macromolecules which are aggregates of different molecule, when placed in magnetic field orient themselves according to field direction and create large effects. For example Beaugnon et al. [11] studied the effect of magnetic field > 20 T on water, ethanol and acetone and all these showed magnetic levitation because of their diamagnetic nature. The distortion of surface of liquid helium at 6.5 T magnetic field is another example. Ueno et al. [12] studied the behavior of water at magnetic field of 8T and a field gradient of 400 T^2/m and observed that the force exerted by magnetic field on water and diamagnetism is the reason behind the splitting observed in water

The maximum percentage of blood is water and so there is a finite probability that the magnetic field has effect on it.

III. PROPOSED WORK

The aim of the present study is to find the effects of static magnetic field on blood. The blood consists of various types of proteins, RBC (which contain hemoglobin), WBC, platelets, lipids, water etc. If blood constituents are considered separately according to their magnetic nature it is found that deoxygenated-hemoglobin, erythrocytes and a few proteins are paramagnetic in nature while most of the proteins, lipids, fibrinogen and water are diamagnetic.

If a magnetic field is applied all molecules behave according to their magnetic nature. Motta et al. [2] and Tzirtzilakis [13] have theoretically shown that there was a decrease in the velocity of blood when it was considered as bio-fluid flowing in a tube and static magnetic field was applied perpendicular to the flow. They the considered force due to magnetization and the Lorentz force, as the cause for this effect. This experiment was performed to verify that there is an effect of magnetic field on the blood.

A. Methodology of Experiment Analysis

2 ml venous (deoxygenated) blood was taken from a healthy human. For analyzing the magnetic effect **Shimadzu (Japan) UV-3600 Spectrophotometer** (Figure-1), with wavelength range 280 nm – 2000 nm was used.

The experimental analysis was conducted in three phases for different blood samples. In the first phase, a 2 ml blood sample was placed in spectrophotometer and transmittance curves were plotted. Then in the second phase, the same blood sample was placed between electromagnets (Figure-2) producing the non-uniform static magnetic field of 3500 Gauss or 0.35 T for 20 minutes, and again transmittance curves were plotted after safely placing it in spectrophotometer. In the third phase, the same blood sample after 20 minutes was again placed in the spectrophotometer for post exposure curve.

Figure-1: Shimadzu UV-3600 Spectrophotometer

The curves were plotted between wavelength and transmittance in all the three phases of experiment i.e. pre-exposure, post-exposure and 20 min after removing magnetic field from the blood sample.Figure-3, 4 and 5 represent the curves plotted in the first, second and third phases respectively.

Figure-2: Electromagnet used in experiment for producing non uniform SMF.

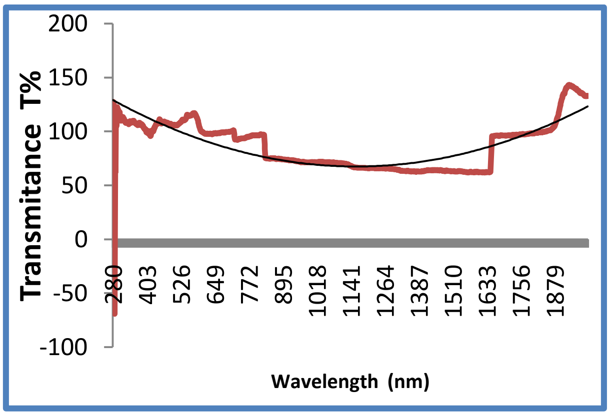

Figure-3: Transmittance curve of blood sample before exposure to SMF

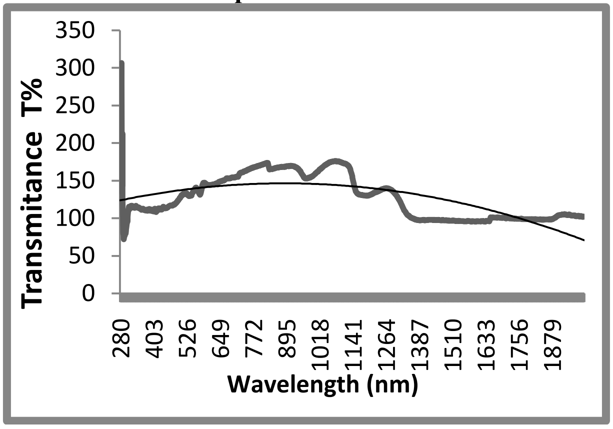

Figure-4: Transmittance curve of blood sample after exposure to SMF

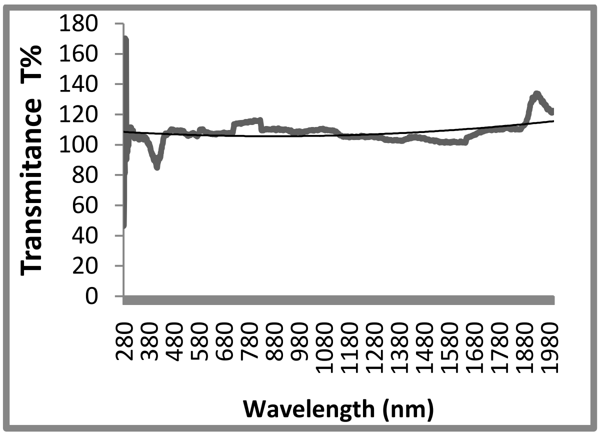

Figure-5: Transmittance curve of blood sample 20 minutes after removing the SMF

|IV. RESULTS AND DISCUSSION

The transmittance curves shown in figures 3 to 4, for blood sample before and after placing in magnetic field of 0.35 T are obtained in wavelength range 280 nm to 2000 nm. The trends of the curves are compared and found that the curves of blood before placing in magnetic field are convex, whereas the curves obtained after placing in magnetic field are concave in nature.

When blood is placed in magnetic field, the magnetic field exerts a force on it and the moment of force i.e. torque rotates the various constituents of blood with respect to the field direction. The magnitude and direction of the force depends upon the field strength and direction of the field. Thus the molecules of blood align themselves according to the field direction and acquire a net dipole moment. The magnetic dipole moment per unit volume gives the magnetization $\vec{M}$ i.e.

$$\vec{m} = \vec{M}\ V$$

Where, $\vec{m}$ is magnetic dipole moment, $\vec{M}$ is magnetization and V is the volume.

This magnetization is uniform if the substance is homogenous and isotropic. Since torque acts on the molecules of blood when placed in an external magnetic field B_0, work must be done to change the orientation of such a dipole. This work done is the potential energy given by

$$U = \vec{m}.\vec{B}_0$$

where B_0 is static magnetic field.

The force exerted on paramagnetic and diamagnetic molecules of the blood pulls the paramagnetic molecules towards the region of higher magnetic field and pushes the diamagnetic molecules towards field of lower strength. This force is given by

$$\vec{F} = -\vec{\nabla}U$$

If the substance has magnetization $\vec{M}$ and field strength $\vec{H}_0$ then susceptibility χ is

$$\chi = \vec{M}/\vec{H}_0$$

$$\vec{m} = \vec{M}\,V$$

$$\vec{m} = \chi\,\vec{H}_0\,V = \frac{\chi}{\mu_0}V\vec{B}_0$$

Hence,

$$U = \vec{m}.\vec{B}_0$$

$$U = -\frac{\chi}{\mu_0}V\,\vec{B}_0^{\,2}$$

Thus the energy of blood is changed. Here B is constant as the molecule of blood is very small.

Thus in the presence of magnetic field the fibrin fibres orient themselves parallel to the field while in its absence of the field, the fibres form a gummed web. The red blood cells or erythrocytes are paramagnetic so they orient themselves in the direction of magnetic field as reported by Shiga et al. [5] & Chen et al. [6] in their study. Thus the magnetic field shifts these molecules and changes the energy of the blood molecules. Therefore, while the blood constituents remain same after application of magnetic field but their homogenous properties are disturbed. A crucial conclusion which can be derived from these curves is that the effect of the field is temporary, which can be seen as after removing the magnetic field the nature of curve reverses from concave to convex. The reason for this is that when the field is removed the energy due to magnetization is overcome by the thermal energy of these molecules so the random motion of molecules gained the homogenous property of the blood and it again shows the same trend in transmittance curve.

V. CONCLUSION

This experimental study clearly indicates that there is an effect of magnetic field on the blood and this effect is most probably due to change in energy of the molecules and the orientation of diamagnetic and paramagnetic molecules during exposure of field, which concludes that the exposure to magnetic field caused the effect. It is however, not possible, at present to conclude whether this effect is harmful or beneficial for the body.

V. REFERENCES

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